PATENT COOPERATION TREATY

From the
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

To: VINCENT A. CICHOSZ
DELPHI TECHNOLOGIES, INC.
PO BOX 5052
MAIL CODE 480-414-420
TROY, MI 48007-5052

PCT

NOTIFICATION OF TRANSMITTAL OF INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Rule 71.1)

Date of Mailing *(day/month/year)*	20 AUG 2002
Applicant's or agent's file reference H-203691	IMPORTANT NOTIFICATION

International application No.	International filing date *(day/month/year)*	Priority Date *(day/month/year)*
PCT/US00/41149	12 OCTOBER 2000	15 OCTOBER 1999

Applicant
DELPHI TECHNOLOGIES, INC.

1. The applicant is hereby notified that this International Preliminary Examining Authority transmits herewith the international preliminary examination report and its annexes, if any, established on the international

2. A copy of the report and its annexes, if any, is being transmitted to the International Bureau for communication to all the elected Offices.

3. Where required by any of the elected Offices, the International Bureau will prepare an English translation of the report (but not of any annexes) and will transmit such translation to those Offices.

4. REMINDER

The applicant must enter the national phase before each elected Office by performing certain acts (filing translations and paying national fees) within 30 months from the priority date (or later in some Offices)(Article 39(1))(see also the reminder sent by the International Bureau with Form PCT/IB/301).

Where a translation of the international application must be furnished to an elected Office, that translation must contain a translation of any annexes to the international preliminary examination report. It is the applicant's responsibility to prepare and furnish such translation directly to each elected Office concerned.

For further details on the applicable time limits and requirements of the elected Offices, see Volume II of the PCT Applicant's Guide.

Name and mailing address of the IPEA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231	Authorized officer T. TANG
Facsimile No. (703) 305-3230	Telephone No. (703) 308-3329

Form PCT/IPEA/416 (July 1992)★

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference H-203691	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
International application No. PCT/US00/41149	International filing date *(day/month/year)* 12 OCTOBER 2000	Priority date *(day/month/year)* 15 OCTOBER 1999
International Patent Classification (IPC) or national classification and IPC IPC(7): G 01 N 27/407 and US Cl.: 205/783.5		
Applicant DELPHI TECHNOLOGIES, INC.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 5 sheets.

   ☐ This report is also accompanied by ANNEXES, i.e., sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority. (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 0 sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the report
   - II ☐ Priority
   - III ☐ Non-establishment of report with regard to novelty, inventive step or industrial applicability
   - IV ☐ Lack of unity of invention
   - V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
   - VI ☐ Certain documents cited
   - VII ☒ Certain defects in the international application
   - VIII ☐ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
27 JULY 2001	02 JULY 2002
Name and mailing address of the IPEA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer T. TUNG Telephone No. (703) 308-3329

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.
PCT/US00/41149

I. Basis of the report

1. With regard to the elements of the international application:*

[X] the international application as originally filed

[X] the description:
pages 1-15 , as originally filed
pages NONE , filed with the demand
pages NONE , filed with the letter of _____

[X] the claims:
pages 16-22 , as originally filed
pages NONE , as amended (together with any statement) under Article 19
pages NONE , filed with the demand
pages NONE , filed with the letter of _____

[X] the drawings:
pages 1-6 , as originally filed
pages NONE , filed with the demand
pages NONE , filed with the letter of _____

[X] the sequence listing part of the description:
pages NONE , as originally filed
pages NONE , filed with the demand
pages NONE , filed with the letter of _____

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.
These elements were available or furnished to this Authority in the following language _____ which is:

[ ] the language of a translation furnished for the purposes of international search (under Rule 23.1(b)).

[ ] the language of publication of the international application (under Rule 48.3(b)).

[ ] the language of the translation furnished for the purposes of international preliminary examination (under Rules 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

[ ] contained in the international application in printed form.

[ ] filed together with the international application in computer readable form.

[ ] furnished subsequently to this Authority in written form.

[ ] furnished subsequently to this Authority in computer readable form.

[ ] The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

[ ] The statement that the information recorded in computer readable form is identical to the writen sequence listing has been furnished.

4. [X] The amendments have resulted in the cancellation of:

[X] the description, pages NONE

[X] the claims, Nos. NONE

[X] the drawings, sheets/~~fig~~ NONE

5. [ ] This report has been drawn as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).**

** Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17).*

***Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.*

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.
PCT/US00/41149

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. statement

Novelty (N)	Claims	2-14, 16-30, 32 and 33	YES
	Claims	1 and 15	NO
Inventive Step (IS)	Claims	NONE	YES
	Claims	1-30, 32 and 33	NO
Industrial Applicability (IA)	Claims	1-30, 32 and 33	YES
	Claims	NONE	NO

2. citations and explanations (Rule 70.7)

Claims 1 and 15 lack novelty under PCT article 33(2) over Murase et al 5,413,693 or Hotzel et al 5,632,883.

Murase discloses a solid electrolyte sandwiched by a measuring electrode 20 and a reference electrode 24. The reference electrode is exposed to a reference gas chamber 26 that contains porous layer 22 that can act as a diffusion limiter. See column 5, line 59 to column 10, line 64.

Hotzel discloses a solid electrolyte sandwiched by a measuring electrode 4 and a reference electrode 5. The reference electrode is exposed to a reference gas chamber 6. A porous conductor lead 10 serves as a diffusion limiter between the reference gas chamber and the ambient. See column 2, line 32-61.

Claims 2-9, 12 and 13 lack an inventive step under PCT article 33(3) over Murase et al or Hotzel et al.

These claims differ from Murase of Hotzel by calling for the reference gas chamber to have certain dimensions.

Dimensions are a matter of routine design choice in the sense of unexpected result.

Claims 10 and 11 lack an invention step under PCT article 33(3) over Murase et al or Hotzel in view of Sawada et al 5,326,597.

These claims differ by calling for the reference gas chamber to contain an oxygen storage material.

Sawada discloses a solid electrolyte sensor with cerium oxide as an oxygen storage material. See column 6, lines 57-65. It would have been obvious for Murase or Hotzel to adopt an oxygen storage to ensure a constant oxygen concentration at the reference electrode.

Claim 14 lacks an inventive step under PCT article 33(3) over Murase et al of Hotzel in view of Mase et al 4,559,126.

This claim differs by calling for a resistor to be connected between the references electrode and a heater.

Mase disclose a resistor 34 connected between a electrode 5 and a heater terminal 11. See figure 4; column 6, lines 18-58. It would have been obvious for Murase or Hotzel to incorporate a resistor between its reference electrode and its heater in view of Mase so as control the current to the heater.

Claims 16-25, 28, 29, 32 and 33 lack an inventive step under

(Continued on Supplemental Sheet.)

VII. Certain defects in the international application

The following defects in the form or contents of the international application have been noted:

Claims are not numbered connectively. Note that the numbering goes from 30 to 32.

Supplemental Box
(To be used when the space in any of the preceding boxes is not sufficient)

Continuation of: Boxes I - VIII

V. 2. REASONED STATEMENTS - CITATIONS AND EXPLANATIONS (Continued):
PCT Article 33(3) over Murase et al or Hotzel in view of De Jong 4,384,935 or Hetrick 4,272,331.

These claims differ by calling for a series of operational steps including applying a voltage, forming oxygen at the reference electrode and transferring the oxygen to the measuring electrode.

De Jong (column 3, line 24 to column 4, line 61) or Hetrick (column 5, line 5 to column 7, line 31) discloses these operational steps for a solid electrolyte sensor. It would been have obvious for Murase et al or Hotzel et al to adopt conventional operational steps in the absence of unexpected result.

Claim 26 and 27 lack an inventive step under PCT Article 33(3) over Murase et al or Hotzel et al in view of De Jong or Hetrick and Sawada et al.

These claims further differ by calling for an oxygen storage material. As discussed before, that is rendered obvious by Sawada.

Claim 30 lacks an inventive step under PCT article 33(3) over Murase et al or Hotzel et al in view of De Jong or Hetrick and Mase et al.

This claim further differs by calling for the heater to be connected to the reference electrode. As discuss before, that is rendered obvious by Mase.

---------- NEW CITATIONS ----------
NONE

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(71) Applicant *(for all designated States except US)*: **DELPHI TECHNOLOGIES, INC.** [US/US]; Legal Staff MC 480-414-420, 1450 West Long Lake Road, Troy, MI 48007-5052 (US).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **WANG, Da, Yu** [—/US]; 2188 Lancer Drive, Troy, MI 48084 (US). **CHADWICK, Wayne, M.** [—/US]; 11322 Woodbridge Drive, Grand Blanc, MI 48439 (US). **KIKUCHI, Paul, Casey** [—/US]; 12824 Clyde Road, Grand Blanc, MI 48430 (US). **GOODWIN, William, Russell** [—/US]; 5169 Georgetown, Grand Blanc, MI 48439 (US). **TAI, Lone-Wren, F.** [—/US]; 380 Silvervale Drive, Rochester Hills, MI 48309 (US). **DETWILER, Eric, J.** [—/US]; 1518 Colleen Lane, Davison, MI 48423 (US). **KENNARD, Frederick, Lincoln, III** [—/US]; 5499 East Holly Road, Holly, MI 48442 (US). **COHA, Jeffrey, T.** [—/US]; 5483 Maple Park Drive, Flint, MI 48507 (US).

(74) Agent: **CURBELO, Pamela, J.**; Cantor Colburn LLP, 55 Griffin Road South, Bloomfield, CT 06002 (US).

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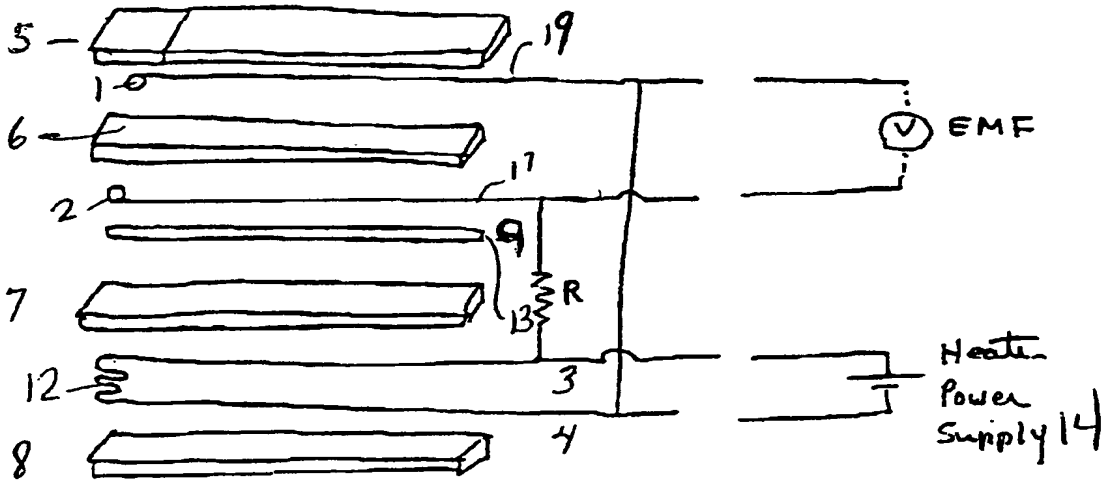
For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: GAS SENSOR DESIGN AND METHOD FOR USING THE SAME



(57) Abstract: The gas sensor employs a reference gas channel which enables simultaneous or sequential pumping of oxygen and sensing of the exhaust gas (e.g., to determine if the exhaust gas is rich or lean). The method comprises: using a gas sensor comprising a first electrode and a reference electrode with an electrolyte disposed therebetween, wherein the first electrode and reference electrode are in ionic communication, and a reference gas channel in fluid communication with the reference electrode and an exterior of the sensor; introducing an exhaust gas to the first electrode; applying a voltage to the reference electrode; ionizing oxygen at the first electrode; transferring the ionized oxygen across the electrolyte to the reference electrode; forming molecular oxygen at the reference electrode; ionizing the molecular oxygen on the reference electrode; transferring the ionized oxygen across the electrolyte to the first electrode to create a voltage; and measuring the voltage.

WO 01/27602 A2

GAS SENSOR DESIGN AND METHOD FOR USING THE SAME

CROSSREFERENCE TO RELATED APPLICATIONS

This case claims the benefit of the filing date of the provisional application U.S. Provisional Application Serial No. 60/159,837 filed October 15, 1999, which is hereby incorporated by reference in its entirety.

TECHNICAL FIELD

This invention relates to gas sensors, and, more particularly, to oxygen sensors.

BACKGROUND OF THE INVENTION

Oxygen sensors are used in a variety of applications that require qualitative and quantitative analysis of gases. In automotive applications, the direct relationship between the oxygen concentration in the exhaust gas and the air-to-fuel ratio of the fuel mixture supplied to the engine allows the oxygen sensor to provide oxygen concentration measurements for determination of optimum combustion conditions, maximization of fuel economy, and the management of exhaust emissions.

A conventional stoichiometric oxygen sensor typically comprises an ionically conductive solid electrolyte material, a porous electrode on the exterior surface of the electrolyte exposed to the exhaust gases with a porous protective overcoat, and an electrode on the interior surface of the sensor exposed to a known oxygen partial pressure. Sensors typically used in automotive applications use a yttria stabilized zirconia based electrochemical galvanic cell with platinum electrodes, which operate in potentiometric mode to detect the relative amounts of oxygen present in the exhaust of an automobile engine. When opposite surfaces of this galvanic cell are exposed to different oxygen partial pressures, an electromotive force is developed between the electrodes on the opposite surfaces of the zirconia wall, according to the Nernst equation:

$$E = \left(\frac{RT}{4F}\right) \ln\left(\frac{P_{O_2}^{ref}}{P_{O_2}}\right)$$

where:

E	=	electromotive force
R	=	universal gas constant
F	=	Faraday constant
T	=	absolute temperature of the gas
$P_{O_2}^{ref}$	=	oxygen partial pressure of the reference gas
P_{O_2}	=	oxygen partial pressure of the exhaust gas

Due to the large difference in oxygen partial pressure between fuel rich and fuel lean exhaust conditions, the electromotive force (emf) changes sharply at the stoichiometric point, giving rise to the characteristic switching behavior of these sensors. Consequently, these potentiometric oxygen sensors indicate qualitatively whether the engine is operating fuel-rich or fuel-lean, conditions without quantifying the actual air-to-fuel ratio of the exhaust mixture.

For example, an oxygen sensor, based on solid oxide electrolyte such as zirconia, measures the oxygen activity difference between an unknown gas and a known reference gas. Usually, the known gas is the atmosphere air while the unknown gas contains the oxygen with its equilibrium level to be determined. Typically, the sensor has a built in air channel which connects the reference electrode to the ambient air. To avoid contamination of the reference air by the unknown gas, the sensor requires expensive sensor package which usually has complex features in order to provide sufficient gas sealing between the reference air and the unknown gas. Historically, these gas sealed sensor packages have demonstrated insufficient durability in the field. This problem can be avoided by using in-situ electrochemical oxygen pumping. In this method, the air reference electrode chamber is replaced by a sealed reference electrode with oxygen electrochemically pumped in from the exhaust gas. This method eliminates the exhaust gas contamination problem but creates its own drawbacks. That is, an expensive electronic circuit is required to do the electrochemical oxygen pumping and excessive oxygen gas pressure built by the oxygen pump current can break open the sensor ceramic body.

What is needed in the art is a simplified gas sensor which employs a electrochemical pumping of oxygen.

BRIEF SUMMARY OF THE INVENTION

A gas sensor and method for using the same. One embodiment of the gas sensor comprises: a first electrode and a reference electrode with an electrolyte disposed therebetween, wherein the first electrode and reference electrode are in ionic communication and a reference gas channel in fluid communication with the reference electrode and an exterior of the sensor, wherein the reference gas chamber has a diffusion limiter.

One embodiment of the method comprises: using a gas sensor comprising a first electrode and a reference electrode with an electrolyte disposed therebetween, wherein the first electrode and reference electrode are in ionic communication and a reference gas channel in fluid communication with the reference electrode and an exterior of the sensor; introducing an exhaust gas to the first electrode; applying a voltage to the reference electrode; ionizing oxygen at the first electrode; transferring the ionized oxygen across the electrolyte to the reference electrode; forming molecular oxygen at the reference electrode; ionizing the molecular oxygen on the reference electrode; transferring the ionized oxygen across the electrolyte to the first electrode to create a voltage; and measuring the voltage.

The above-described and other features and advantages of the present invention will be appreciated and understood by those skilled in the art from the following detailed description, drawings, and appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

The apparatus and method will now be described by way of example, with reference to the accompanying drawing, which is meant to be exemplary, not limiting.

Figure 1 is an expanded view of a gas sensor design.

Figure 2 is a graphical representation of exhaust flux measured from a gas-diffusion-limiting air channel against the leakage rates of the sensor package, the plateau of the data represents the limiting value of the exhaust flux.

Figure 3 is a graphical representation of limiting exhaust flux values against the width distribution (in percent (%)) of the air channels.

Figure 4 is an angled top view of one air channel design that has gas limiting means as well as gas buffering (storage) space to overcome oxygen pump problem related to the heater cyclic operation (heater on-off operation).

Figure 5 is an expanded view of alternative design of a gas sensor which has electrical isolation (ground isolation between the heater and the sensor emf) where the emf element and oxygen pump element are on the opposite side of the heater.

Figure 6 is an expanded view of alternative design of a gas sensor which has electrical isolation (ground isolation between the heater and the sensor emf) where the emf sensor and oxygen pump sensor are on the same side of the heater.

Figure 7 is an expanded view of an alternative gas sensor design with connection of the emf electrode leads and the heater leads outside of the sensor element level to further address the issue of isolation between emf electrode leads and the heater leads.

DETAILED DESCRIPTION OF THE INVENTION

The gas sensor comprises one or more electrochemical cells (i.e., an electrolyte disposed between two electrodes; an exhaust side electrode and a reference electrode), a porous protective layer disposed adjacent to the outer electrode, a reference gas chamber in fluid communication with the reference electrode, and a heater in thermal communication with the electrochemical cell. The reference gas chamber is additionally in fluid communication with the atmosphere around the gas sensor, i.e., the air and the exhaust gas. The reference chamber does not need to be hermetically sealed from the exhaust gas. The gas sensor avoids the requirement of hermetic sealing the reference gas chamber by pumping-in oxygen to the reference electrode and reference chamber thereby

creating a pressure gradient through the chamber. Optionally, one or more gas diffusion limiters may also be employed within the reference chamber.

Referring to Figure 1, the Nernst oxygen sensor is shown with the following basic features (components): exhaust side electrode 1, reference electrode 2, heater leads 3 and 4, porous protection layer 5, solid electrolyte layer 6, insulated alumina layers 7 and 8, air channel 9, and heater 12. In Figure 1, the exhaust gas electrode 1, is exposed to the exhaust gas through the porous protection layer 5. Reference electrode 2 is separated from exhaust electrode 1 by a dense solid electrolyte layer 6 and is exposed to the open channel 9 which is open to the ambient atmosphere at the tail 13 of the sensor. The heater leads 3 and 4 are connected to the positive and negative poles of a heater power supply 14, respectively. Optionally, the sensor can have the positive heater lead 3 connected to the reference electrode lead 17 through resistor R, and the heater negative lead 4 connected to the exhaust side lead 19. In this embodiment, there is a resistor R disposed between leads 3 and 17, thereby enabling the connections and the resistor to optionally be disposed inside the sensor ceramic body.

During use, the exhaust gas migrates to the electrode 1 through the protection coating layer 5 and generates an emf between exhaust electrode 1 and reference electrode 2. To keep reference electrode 2 at a constant oxygen activity, oxygen flux is pumped into electrode 2 by electric power supplied from heater lead 3 with a positive polarity maintained at the reference electrode 2. The oxygen generated at the reference electrode 2 will diffuse out of the reference gas channel 9 through the open end 13 into the ambient atmosphere (e.g., in to the exhaust gas or air).

The diffusion rate out of the reference gas chamber 9/9' (see Figures 1 and 4) is linearly proportional to the difference of oxygen pressure between reference electrode (which is equal to or larger than about 1 atmosphere) and the ambient atmosphere (atm.) (which is equal to or smaller than about 0.21 atmosphere). Because there is no gas diffusion limiting process employed in this embodiment, the pressure of oxygen within the reference gas channel will never build up to a level to damage the ceramic sensor body. Meanwhile, the diffusion rate into the reference gas chamber by air and/or exhaust gas is linearly

proportional to the fuel concentration difference between the reference electrode (where the fuel concentration is kept at zero by the oxygen generated from the pump current) and the ambient atmosphere (which is typically about 21% or less). Since the fuel concentration difference doesn't exceed 21%, the exhaust flux is limited and can be described by Equation I:

$$F_{exh} = \frac{DCA}{L} \qquad (I)$$

where: F_{exh} is the exhaust gas flux (i.e., the rate of exhaust gas migration through the channel)
D is the diffusion constant of exhaust gas constant
C is the ambient atm. exhaust gas concentration at the open end of the reference gas channel;
A is the average cross-sectional area of the gas channel; and
L is the length of the gas channel.

To keep the fuel concentration near zero at the reference electrode, the oxygen flux has to be larger than the limiting flux of the fuel. The amount of the oxygen flux is adjustable by the resistance value of R in Figure 1 and the heater voltage; wherein the amount of the limiting flux of the fuel is determined by the cross-sectional area and the length of the gas channel.

The gas sensor components, i.e., protective layer 5, electrodes 1, 2, 3, and 4 (and leads thereto), heater 12, dielectric layers 7 and 8, and heater supply 14. Furthermore, in addition to these conventional components, additional conventional components can be employed, including but not limited to additional protective coatings (e.g., spinel, alumina, magnesium aluminate, and the like, as well as combinations comprising at least one of the foregoing coatings), lead gettering layer(s), ground plane(s), support layer(s), additional electrochemical cell(s), and the like.

Dielectric layers 7 and 8 and any support layers typically comprise alumina or a similar material that is capable of inhibiting electrical communication and providing physical protection. Preferably, layers 7,8 as well as optional support layers are preferably capable of effectively protecting various portions of the gas sensor, provide structural integrity, separate various components, electrically isolate heater 12 from the sensor circuits, cover reference electrode 2,

heater 12, and/or lead(s), provide physical protection against abrasion, and/or electrically isolate the components of the gas sensor from the packaging. Preferably, the materials employed in the manufacture of gas sensor comprise substantially similar coefficients of thermal expansion, shrinkage characteristics, and chemical compatibility in order to minimize, if not eliminate, delamination and other processing problems.

The dielectric, as well as support layers can each be up to about 200 microns thick, with a thickness of about 50 microns to about 200 microns preferred. These layers can be formed using ceramic tape casting methods or other methods such as plasma spray deposition techniques, screen printing, stenciling and others conventionally used in the art.

Disposed between two of the layers, e.g., 7 and 8 is heater 12, with a ground plane (not shown) optionally disposed between two support layers (not shown. Heater 12 can be any conventional heater capable of maintaining sensor end (i.e., end opposite open end 13) at a sufficient temperature to facilitate the various electrochemical reactions therein. Heater 12, which is platinum, alumina, palladium, and the like, as well as mixtures and alloys comprising at least one of the foregoing metals, or any other conventional heater, is generally screen printed onto a substrate to a thickness of about 5 microns to about 50 microns.

Leads 17 and 19 are disposed across various dielectric layers to electrically connect the external wiring of the gas sensor with electrodes 1, 2. Leads are typically formed on the same layer as the electrode to which they are in electrical communication and extend from the electrode to the terminal end of the gas sensor where they are in electrical communication with the corresponding via (not shown). Heater 12 also has leads 3 and 4 that are in electrical communication with vias.

In electrical communication with the leads are electrodes which are in ionic communication with the electrolyte. Electrolyte layer 6, 6', 6", which is preferably a solid electrolyte that can comprise the entire layer or a portion thereof (see Figures 1, and 5 - 7), can be any material that is capable of permitting the electrochemical transfer of oxygen ions while inhibiting the physical passage of exhaust gases, has an ionic/total conductivity ratio of approximately unity, and is

compatible with the environment in which the gas sensor will be utilized (e.g., up to about 1,000°C). Also, this electrolyte can be formed via many conventional processes including, but not limited to, die pressing, roll compaction, stenciling and screen printing, tape casting techniques, and the like. Possible solid electrolyte materials can comprise any material conventionally employed as sensor electrolytes, including, but not limited to, zirconia which may optionally be stabilized with calcium, barium, yttrium, magnesium, aluminum, lanthanum, cesium, gadolinium, and the like, as well as combinations comprising at least one of the foregoing. For example, the electrolyte can be alumina and yttrium stabilized zirconia. Typically, the solid electrolyte has a thickness of up to about 500 microns, with a thickness of approximately 25 microns to about 500 microns preferred, and a thickness of about 50 microns to about 200 microns especially preferred.

It should be noted that, in some embodiments, a porous electrolyte may also be employed. The porous electrolyte should be capable of permitting the physical migration of exhaust gas and the electrochemical movement of oxygen ions, and should be compatible with the environment in which the gas sensor is utilized. Typically, porous electrolyte has a porosity of up to about 20%, with a median pore size of up to about 0.5 microns, or, alternatively, comprises a solid electrolyte having one or more holes, slits, or apertures therein, so as to enable the physical passage of exhaust gases. Commonly assigned U.S. Patent No. 5,762,737 to Bloink et al., which is hereby incorporated in its entirety by reference, further describes porous electrolytes that may be useful in the instant application. Possible porous electrolytes include those listed above for the solid electrolyte.

It should be noted that the electrolytes 6,6',6" and protective material 5 can comprise entire layer or any portion thereof; e.g. they can form the layer, be attached to the layer (protective material/electrolyte abutting dielectric material), or disposed an opening in the layer (protective material/electrolyte can be an insert). The latter arrangement eliminates the use of excess electrolyte and protective material, and reduces the size of gas sensor by eliminating layers. Any shape can be used for the electrolyte and protective material, with the size and geometry of the various inserts, and therefore the corresponding openings, being

dependent upon the desired size and geometry of the adjacent electrodes. It is preferred that the openings, inserts, and electrodes have a substantially similar geometry.

The various electrodes 1, 2, 10, and 11 disposed in contact with electrolyte 6,6',6" (see Figures 1, and 5 - 7) and porous electrolyte can comprise any catalyst capable of ionizing oxygen, including, but not limited to, metals such as platinum, palladium, osmium, rhodium, iridium, gold, and ruthenium; metal oxides such as zirconia, yttria, ceria, calcia, alumina and the like; other materials, such as silicon, and the like; and mixtures and alloys comprising at least one of the foregoing catalysts.

Electrodes 1, 2, 10, and 11 can be formed using conventional techniques such as sputtering, chemical vapor deposition, screen printing, and stenciling, among others, with screen printing the electrodes onto appropriate tapes being preferred due to simplicity, economy, and compatibility with the subsequent co-fired process. For example, reference electrode 2 can be screen printed onto dielectric layer 7 or over the solid electrolyte 6, exhaust electrode 1 can be screen printed over solid electrolyte 6 or on protective layer 5. Electrode leads and vias in the dielectric and/or electrolyte layers (not shown) are typically formed simultaneously with electrodes.

Disposed in fluid communication with the reference electrode 2 is the reference gas channel 9,9' formed by depositing a carbon base material, i.e., a fugitive material such as carbon black, between reference electrode 2 and layer 7 such that upon processing the carbon burns out, and leaves a void. (See Figures 1 and 4) As is evident from Figure 4, the geometry of the reference chamber can be altered to accommodate the particular application. In this particular embodiment, the reference gas channel 9' comprises two diffusion paths 21 and 23, with two chambers 23 and 25. The length and cross-sectional area of the various compartments (21, 23, 25, and 27) of the reference gas channel 9' are determined based upon Equation I above and the exhaust flux. In this embodiment two chambers and two diffusion paths are employed to account for a cycling of the heater voltage. Essentially, when no voltage is applied to the heater, no voltage is applied to the electrodes to induce pumping into the reference gas channel. To

inhibit ambient atm. access to the reference electrode, the multi-stage diffusion channel is employed. Where the voltage employed for pumping is not cyclical, a single chamber and channel can be employed. Here, the channel and chamber can be the same or a different size, based upon Equation I and the voltages to be employed.

The oxygen pump current has to be larger than the fuel limiting current in order to move oxygen across the electrolyte into the reference gas channel. However, if the current is too large it can create additional polarization at electrolyte (ohmic drop) and at electrodes (electrode polarization) which will create error signal to the emf measurement, especially during the light off time of the sensor operation. Consequently, a pump current of about 30 milliamperes per square centimeter (mA/cm^2) or less of the exhaust electrode area can be used, with about 20 mA/cm^2 or less preferred, and about 10 mA/cm^2 or less especially preferred. This requirement can be achieved for example by selecting the right resistance value of R (see Figure 1), depending on the heater voltage used. The resistor can be carbon or metal oxide type resistor or can be thick film type which can be screen printed on the sensor ceramic body. If the heater uses an alternating current (ac) power supply, a diode can optionally be added to the circuit (in series with R, see Figure 1).

Due to the fuel limiting current, the reference gas channel should have a physical dimension to attain a limiting exhaust gas flux of about 30 milliamperes per square centimeter (mA/cm^2) of the electrode area or less, with about 20 mA/cm^2 or less preferred, and about 10 mA/cm^2 or less especially preferred. Since the various parameters are interrelated, various amounts can be employed, depending upon the particular design of the sensor. The design should be based upon a combination of the Equation I above, and Equation II:

$$I_p = \frac{V_h \quad V_{emf}}{R} \qquad \text{(II)}$$

where: I_p is the pump current;
V_h is the heater voltage;
V_{emf} is the sensor emf; and
R is the resistance of the resistor.

Generally, for a voltage of about 10 to about 21 volts (V), the channel length (L) can be about 35 mm to about 65mm, a width (W) of about 0.50 mm or less, and a height (H) of about 0.05mm or less; with a length of about 35mm to about 50mm, a width of about 0.30mm or less, and a height of about 0.025mm or less preferred; and a length of about 40mm to about 48mm, a width of about 0.13mm or less, and a height of about 0.015mm or less especially preferred. It should be noted that the lower limit of the cross-sectional area (i.e., width times height) is based upon the desired diffusion rates. Although, the lower limits of both the width and height are about 0.005mm, the practical lower limits are substantially higher due to available production equipment limitations. For example, with a nominal V_h of about 13.5 volts, R of about 2 megaohms (MΩ), I_p of about 7 microampheres (ΠA), the dimensions of the channel are about 43 mm (L) by 0.2 mm (W) by 0.02mm (H).

Production of the reference gas channel can be accomplished via mechanical cutting-in duck, screen-printing fugitive material (such as carbon which can be burned off at high temperature), porosity controlled coating layering, laser drilling holes, and the like. For example, the channel can be open to the ambient exhaust gas directly at the tip (13 in Figure 1) of the gas sensor with a channel dimension of about 10 millimeters (mm) in length (L) by 0.007mm in width (W) by 0.01mm in height (H).

The heater or any other power device may be the power source for oxygen pumping. If the heater is the source and is operating in a cyclic mode, there is a period of time when no oxygen pumping occurs. If such period of time lasts too long, oxygen can be depleted at the reference electrode. A buffer zone can add into the gas channel design to avoid such difficulties. (See Figures 4-6) In these Figures, the reference electrode sits adjacent a small chamber 25 and a large chamber 27 functions as the buffer zone with a short diffusion-limiting path 21 connecting to the small chamber and a long diffusion path 23 connecting to the tail of the gas sensor. Pumped-in oxygen will be stored in the buffered zone to sustain the reference electrode over the period of time when no oxygen is supplied. Such gas channel can be made by screen printing with fugitive materials such as graphite or carbon which can be burned off during the sintering step. Oxygen storage

materials can also optionally be added to all or a portion of the reference gas channel (e.g., to the entire channel, to one or more diffusion paths, to one or more chambers, or to any combination of these channel portions) to increase the effectiveness of its function. Such materials include metals such as platinum, rhodium, palladium, ruthenium, iridium, osmium, and the like; metal oxides such as cerium oxide and bismuth oxide, and the like; as well as other conventional oxygen storage materials, and mixtures and alloys comprising at least one of the foregoing materials. Commonly assigned application, Attorney Docket No. DP-300023, U.S. Application Serial No. 09/476,834 to Detwiler, filed January 3, 2000, which is hereby incorporated in its entirety by reference, further describes oxygen storage materials that may be useful in the instant application.

In an alternative embodiment, electric isolation can be established between the heater and the emf element by employing an additional isolated pair of electrodes to do the oxygen pumping. Possible ways to do so are illustrated in Figures 5 and 6. Figure 5 shows a symmetrical design. The sensor has two almost identical sensor layouts similar to the one shown in Figure 1 but put on opposite sides of the ceramic heater. One of the sensors has an opening reference gas channel with its two leads 3 and 4 connected to the heaters. The other sensor has a gas channel through the heater ceramic to expose one of its electrodes (2) to the oxygen generated by the pump electrodes 10 and 11 and measures emf by electrodes 1 and 2. Since electrodes 1, 2 are electrically isolated from electrodes 10 and 11, this sensor design has the feature of signal ground isolation. Also because of electrodes 1 and 2 are separated from electrodes 10 and 11, the maximum oxygen pump current is not limited to 30 mA/cm^2. the hole through the ceramic heater can be made by mechanical punching, drilling on the green tapes before the thermal lamination step.

Figure 6 shows another possible design that can achieve the same signal isolation. This time the emf sensing electrodes 1 and 2 and the oxygen pump electrodes 10 and 11 are put on the same side of the heater. Electrical isolation layer (e.g., a dielectric layer) such as alumina is put in between the two solid electrolytes cladded between the electrodes. The two isolated electrolytes can be in the form of button or strip. The open reference gas channel connects

both electrodes 2 and 4. The two pairs of electrodes can be side by side or one after the other.

Still there is another way to improve the signal-noise isolation. We can take away the connection between electrodes 1 and 4 from sensor element level (see Figure 1) and reconnect at the control board level as shown in Figure 7. A resistance R2 will add to give the feature of virtual ground isolation. In comparison with the method shown in Figures 4(a) and 4(b), this scheme is simpler.

During use, exhaust electrode 1, electrolyte 6, and reference electrode 2 form both a pumping cell and a reference cell, which can operate, even simultaneously. Oxygen in the exhaust enters the pumping cell through protective layer 5 where a voltage applied across electrodes 1 and 2 cause oxygen on electrode 1 to be ionized and pumped to reference electrode 2. Then the oxygen is available to provide the reference gas to determine whether the exhaust gas at the exhaust electrode fuel rich (A/F is less than about 14.7 for a gas engine) or fuel lean (A/F is greater than about 14.7 for a gas engine).

The following example is merely intended to further illustrate an embodiment of the invention and not to limit the scope thereof.

EXAMPLE

Alumina and yttria doped zirconia were mixed with binders, plasticizers, and solvents and roll-milled into slurry as is conventional. The slurry was then casted into tapes by doctor blade tape casting methods.

Platinum inks and carbon inks were screen printed onto the tapes in the structure as shown in Figure 1 (electrodes 1, 4 were platinum and reference gas channel 9 was carbon). The print of the carbon channel 9 had a basic physical dimension of 49 mm L by 0.86mm W by 0.015mm H; with the W varied at 13%, 20%, 25%, 50% and 100% of the value shown here. The reference gas channel had openings at the tail end of the gas sensor.

The tapes were thermally laminated, cut and co-fired at 1,500°C for several hours and later packaged for final testing. Because the sensors were new

and hermetically sealed, various sizes of leak holes were made into the sensor packages so that exhaust gas could leak into the tail part of the sensors.

The sensors were then operated in hot rich engine operation conditions (e.g., 5.7 liter (l), eight valve (V8) engine at 2,700 revolutions per minute (rpm) and 70 kilopascals (kPa) exhaust pipe back-pressure, 10% rich from stoichiometric point (i.e., an A/F of about 13.2) , and an exhaust temperature 850°C), the limiting exhaust gas flux measured in terms of electrical current was measured as a function of the leak rate (which was measured against air at room temperature with a vacuum pump).

The results which demonstrate the diffusion limiting effect of the air channel on the exhaust flux are shown in Figure 2, in which the fuel limiting current is plotted against the logarithmic leak rate (in cubic centimeters per second (cm^3/sec)) of the sensor package. The observed limiting current plateau is 5 micro-ampere (mA) which indicates the exhaust flux diffused into the reference gas channel has a limiting value irregardless of the amount to which the exhaust gas contaminated the ambient atmosphere.

If oxygen was pumped into the reference chamber (i.e., up to 1.5 volts (V) directly applied between the exhaust electrode and reference electrode), the reference gas channel doesn't break. In other words, in contrast to a sealed reference gas channel, the current reference gas channel can withstand oxygen being pumped in at a voltage up to and even exceeding about 1.5 V without cracking due to excessive internal oxygen pressure build-up. This proves the reference gas channel indeed has a one-way-gas-diffusion-limiting feature. It limits the exhaust flux but does not limit the flow of oxygen and build up the oxygen pressure at the reference electrode to the point of cracking.

Next, the fuel limiting flux was measured as a function of the width of the reference channel. The results are plotted in Figure 3, in which the limiting exhaust flux are plotted against the percentage change of the width of the reference channel. As can be seen in this Figure, the limiting exhaust flux is linearly proportional to the linear dimension of the reference gas channel.

Due to the design of the gas sensor and especially the reference gas channel, diffusion of exhaust gas or contaminated air toward the reference

electrode is inhibited. This, in conjunction with the electrochemical pump method, eliminates the requirement of hermetic seal sensor package and the oxygen-pressure-buildup problem, and eliminates the expensive power supply and electronic circuit. A further advantage of the sensor, is, when a co-fired embodiment is employed, the production is simplified due to the ability to use fugitive material in the formation of the reference gas channel.

While preferred embodiments have been shown and described, various modifications and substitutions may be made thereto without departing from the spirit and scope of the invention, including the use of the geometries taught herein in other conventional sensors. Accordingly, it is to be understood that the apparatus and method have been described by way of illustration only, and such illustrations and embodiments as have been disclosed herein are not to be construed as limiting to the claims.

We claim:

1. A gas sensor, comprising:

a first electrode and a reference electrode with an electrolyte disposed therebetween, wherein the first electrode and reference electrode are in ionic communication; and

a reference gas channel in fluid communication with the reference electrode and an exterior of the sensor, wherein the reference gas chamber has a diffusion limiter.

2. A gas sensor as in Claim 1, wherein the reference gas channel has a limiting exhaust flux of about 30 mA/cm^2 or less of reference electrode area.

3. A gas sensor as in Claim 2, wherein the reference gas channel has a limiting exhaust flux of about 20 mA/cm^2 or less of the reference electrode area.

4. A gas sensor as in Claim 3, wherein the reference gas channel has a limiting exhaust flux of about 10 mA/cm^2 or less of the reference electrode area.

5. A gas sensor as in Claim 3, wherein the reference gas channel has a size determined by Equation (I):

$$F_{exh} = \frac{DCA}{L} \qquad (I)$$

where F_{exh} is the exhaust gas flux (i.e., the rate of exhaust gas migration through the channel); D is the diffusion constant of exhaust; C is the ambient atm. fuel concentration at the open end of the reference gas channel; A is the average cross-sectional area of the gas channel; and L is the length of the gas channel.

6. A gas sensor as in Claim 5, wherein design of the reference gas channel is further based upon Equation (II):

$$I_p = \frac{V_h \quad V_{emf}}{R} \qquad (II)$$

where I_p is pump current; V_h is heater voltage; V_{emf} is sensor emf; and R is resistor resistance.

7. A gas sensor as in Claim 1, wherein the reference gas channel has a length of about 35 mm to about 65mm, a width of about 0.50 mm or less, and a height of about 0.05mm or less.

8. A gas sensor as in Claim 7, wherein the length is about 35mm to about 50mm, the width is about 0.30mm or less, and the height is about 0.025mm or less.

9. A gas sensor as in Claim 8, wherein the length is about 40mm to about 48mm, the width is about 0.13mm or less, and the height is about 0.015mm or less.

10. A gas sensor as in Claim 1, wherein the reference gas channel further comprises an oxygen storage material.

11. A gas sensor as in Claim 10, wherein the oxygen storage material is selected from the group consisting of platinum, rhodium, palladium, ruthenium, iridium, osmium, cerium oxide, bismuth oxide, and mixtures and alloys comprising at least one of the foregoing materials.

12. A gas sensor as in Claim 1, wherein the reference gas channel further comprises a first chamber disposed adjacent to the reference electrode, wherein the first chamber has a cross-sectional area greater than a diffusion limiter cross-sectional area.

13. A gas sensor as in Claim 12, wherein the reference gas channel further comprises a second chamber further comprises a second chamber and a second diffusion path, wherein the second chamber is disposed in fluid communication with the first chamber, with the first diffusion path disposed therebetween, and the second diffusion path is disposed in fluid communication with the first diffusion path, with the second chamber disposed therebetween, and the second chamber has a cross-sectional area greater than the first chamber cross-sectional area and the second diffusion path has a cross-sectional area smaller than the first chamber cross-sectional area.

14. A gas sensor as in Claim 1, wherein the sensor further comprises a heater and a resistor, wherein the resistor is connected to a positive heater lead and to the reference electrode.

15. A gas sensor as in Claim 1, further comprising co-firing the sensor.

16. A method for operating a gas sensor, comprising:

using a gas sensor, the sensor comprising a first electrode and a reference electrode with an electrolyte disposed therebetween, wherein the first electrode and reference electrode are in ionic communication, and a reference gas channel in fluid communication with the reference electrode and an exterior of the sensor;

introducing an exhaust gas to the first electrode;

applying a voltage to the reference electrode;

ionizing oxygen at the first electrode;

transferring the ionized oxygen across the electrolyte to the reference electrode;

forming molecular oxygen at the reference electrode;

ionizing the molecular oxygen on the reference electrode;

transferring the ionized oxygen across the electrolyte to the first electrode to create a voltage; and

measuring the voltage.

17. The method for operating a gas sensor as in Claim 16, wherein the reference gas channel further comprises a diffusion limiter.

18. The method for operating a gas sensor as in Claim 16, wherein the reference gas channel has a limiting exhaust flux of about 30 mA/cm^2 or less of reference electrode area.

19. The method for operating a gas sensor as in Claim 18, wherein the reference gas channel has a limiting exhaust flux of about 20 mA/cm^2 or less of the reference electrode area.

20. The method for operating a gas sensor as in Claim 19, wherein the reference gas channel has a limiting exhaust flux of about 10 mA/cm^2 or less of the reference electrode area.

21. The method for operating a gas sensor as in Claim 16, wherein the reference gas channel has a size determined by Equation (I):

$$F_{exh} = \frac{DCA}{L} \qquad (I)$$

where F_{exh} is the exhaust gas flux (i.e., the rate of exhaust gas migration through the channel); D is the diffusion constant of exhaust; C is the ambient atm. fuel concentration at the open end of the reference gas channel; A is the average cross-sectional area of the gas channel; and L is the length of the gas channel.

22. The method for operating a gas sensor as in Claim 21, wherein design of the reference gas channel is further based upon Equation (II):

$$I_p = \frac{V_h \quad V_{emf}}{R} \qquad (II)$$

where I_p is pump current; V_h is heater voltage; V_{emf} is sensor emf; and R is resistor resistance.

23. The method for operating a gas sensor as in Claim 22, wherein the reference gas channel has a length of about 35 mm to about 65mm, a width of about 0.50 mm or less, and a height of about 0.05mm or less.

24. The method for operating a gas sensor as in Claim 23, wherein the length is about 35mm to about 50mm, the width is about 0.30mm or less, and the height is about 0.025mm or less.

25. The method for operating a gas sensor as in Claim 24, wherein the length is about 40mm to about 48mm, the width is about 0.13mm or less, and the height is about 0.015mm or less.

26. The method for operating a gas sensor as in Claim 16, wherein the reference gas channel further comprises an oxygen storage material.

27. The method for operating a gas sensor as in Claim 26, wherein the oxygen storage material is selected from the group consisting of platinum, rhodium, palladium, ruthenium, iridium, osmium, cerium oxide, bismuth oxide, and mixtures and alloys comprising at least one of the foregoing materials.

28. The method for operating a gas sensor as in Claim 16, wherein the reference gas channel further comprises a first chamber disposed adjacent to the reference electrode, wherein the first chamber has a cross-sectional area greater than a diffusion limiter cross-sectional area.

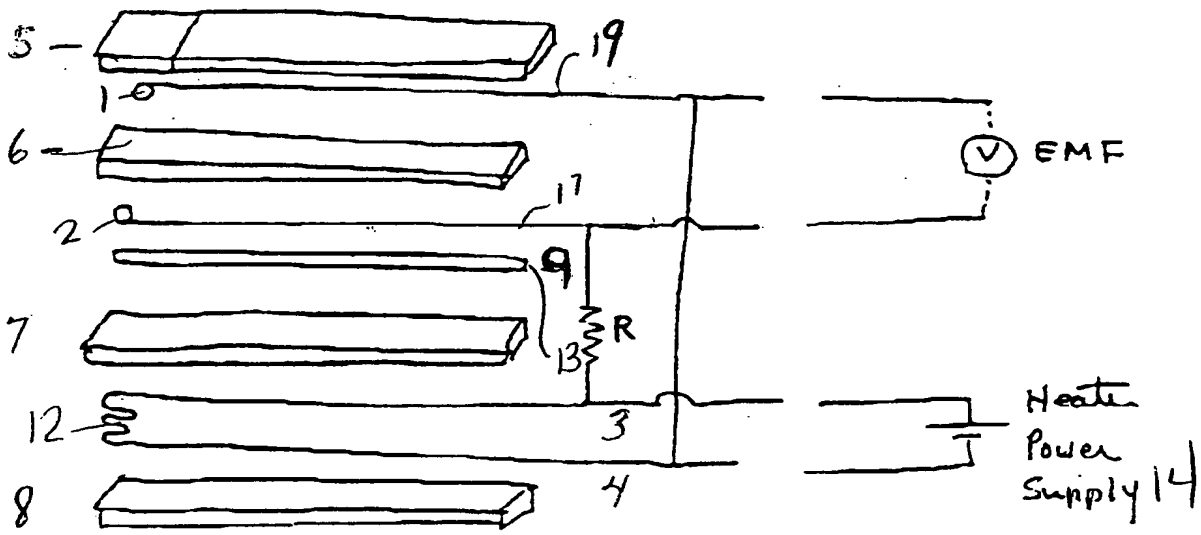
29. The method for operating a gas sensor as in Claim 29, wherein the reference gas channel further comprises a second chamber and a second diffusion path, wherein the second chamber is disposed in fluid communication with the first chamber, with the first diffusion path disposed therebetween, and the second diffusion path is disposed in fluid communication with the first diffusion path, with the second chamber disposed therebetween, and the second chamber has a cross-sectional area greater than the first chamber cross-sectional area and the second diffusion path has a cross-sectional area smaller than the first chamber cross-sectional area.

30. The method for operating a gas sensor as in Claim 29, further comprising a heater electrically connected to the reference electrode, wherein a voltage is cyclically applied to the heater.

32. The method for operating a gas sensor as in Claim 16, wherein the operations of ionizing oxygen at the first electrode, transferring the ionized oxygen across the electrolyte to the reference electrode, and forming molecular oxygen at the reference electrode, occur substantially simultaneously with the operations of ionizing the molecular oxygen on the reference electrode, and transferring the ionized oxygen across the electrolyte to the first electrode to create a voltage.

33. The method for operating a gas sensor as in Claim 16, wherein the gas sensor further comprises a heater, and wherein the sensor has been co-fired.

Figure 1.



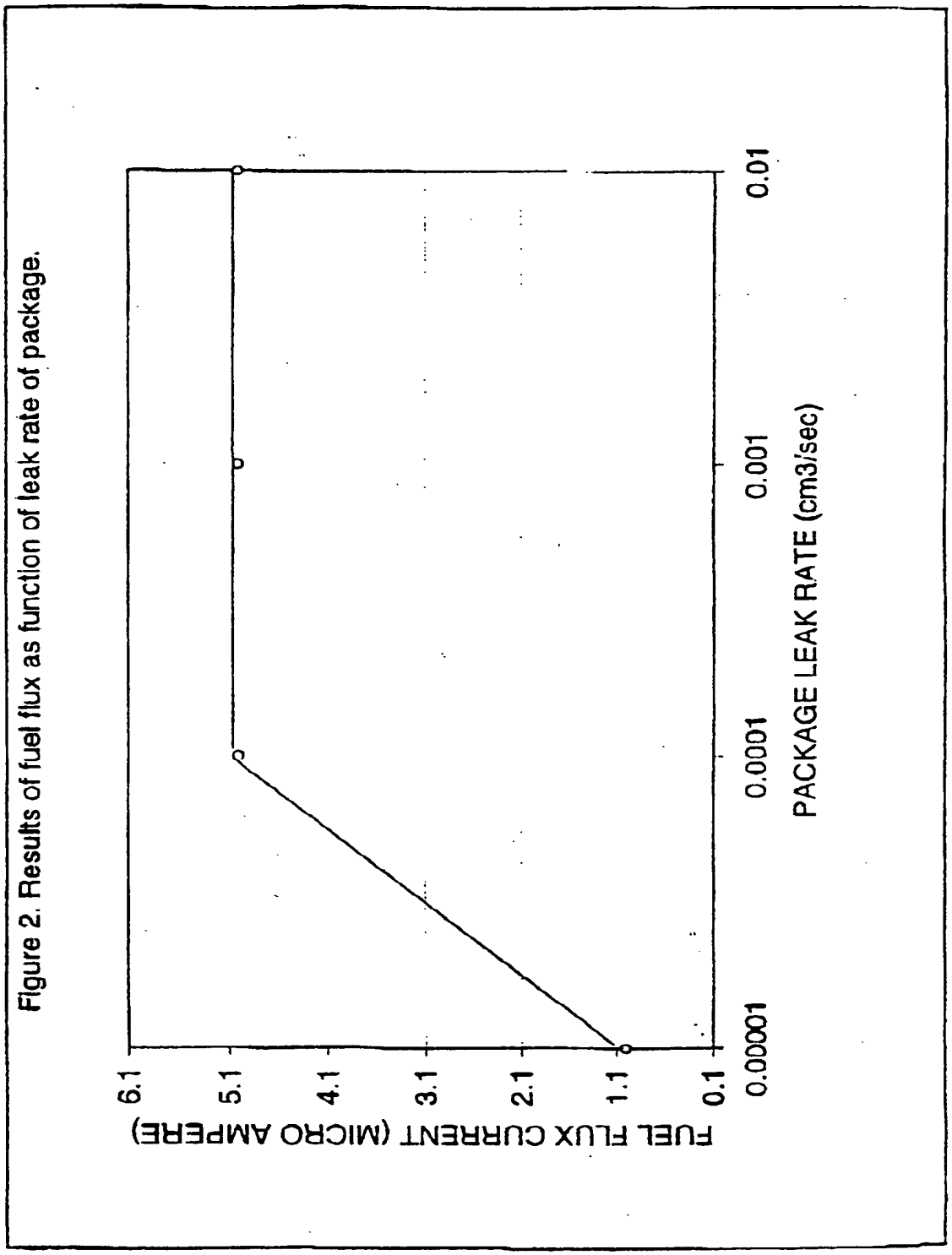


Figure 2. Results of fuel flux as function of leak rate of package.

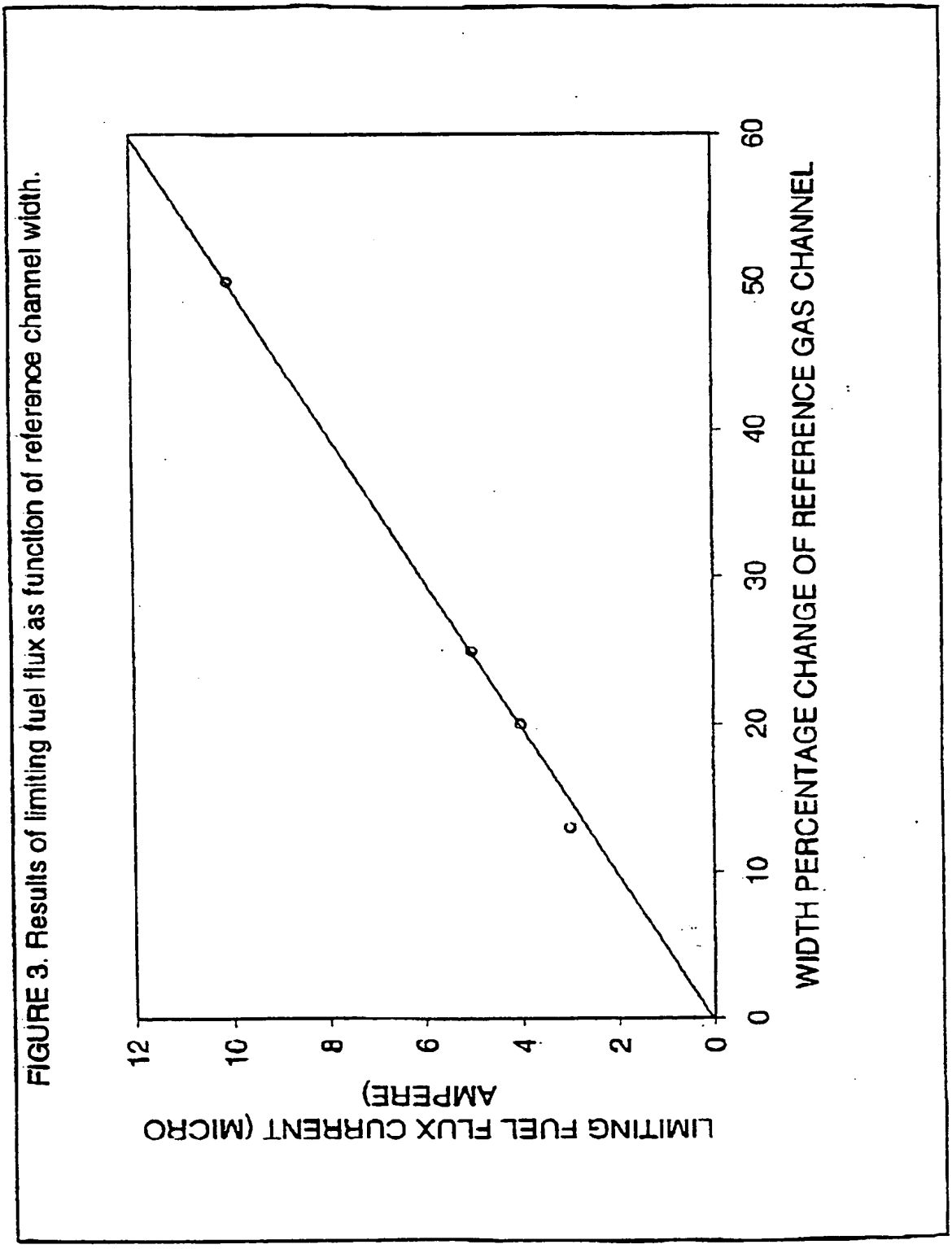


FIGURE 3. Results of limiting fuel flux as function of reference channel width.

Figure 4. Layout of gas channel for heater cycling condition

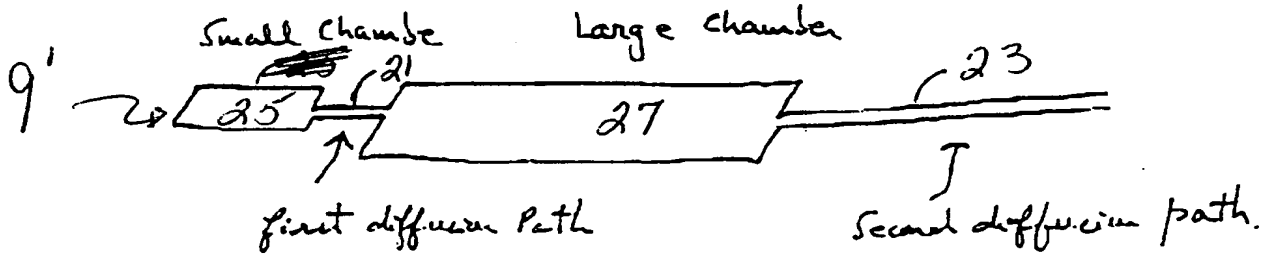


Figure 5. Alternative sensor layouts

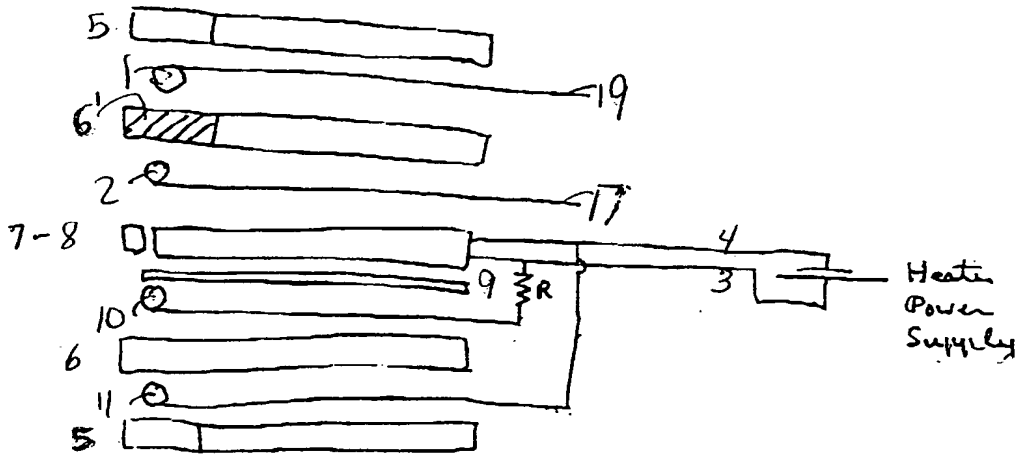


Figure 6

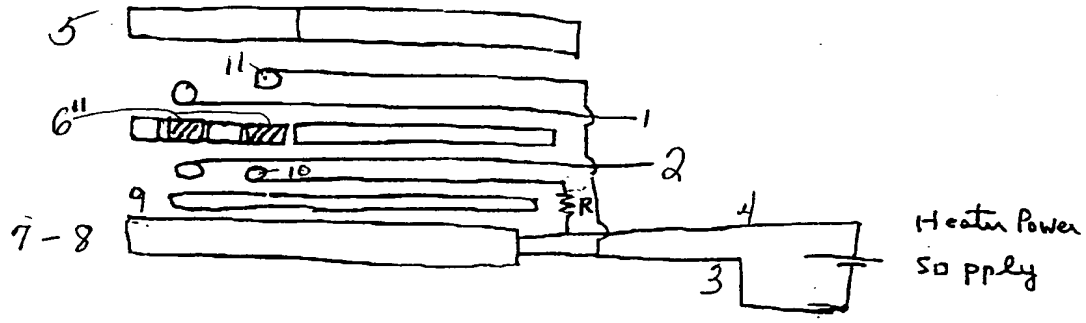


Fig. 7. ... with ground isolation feature.

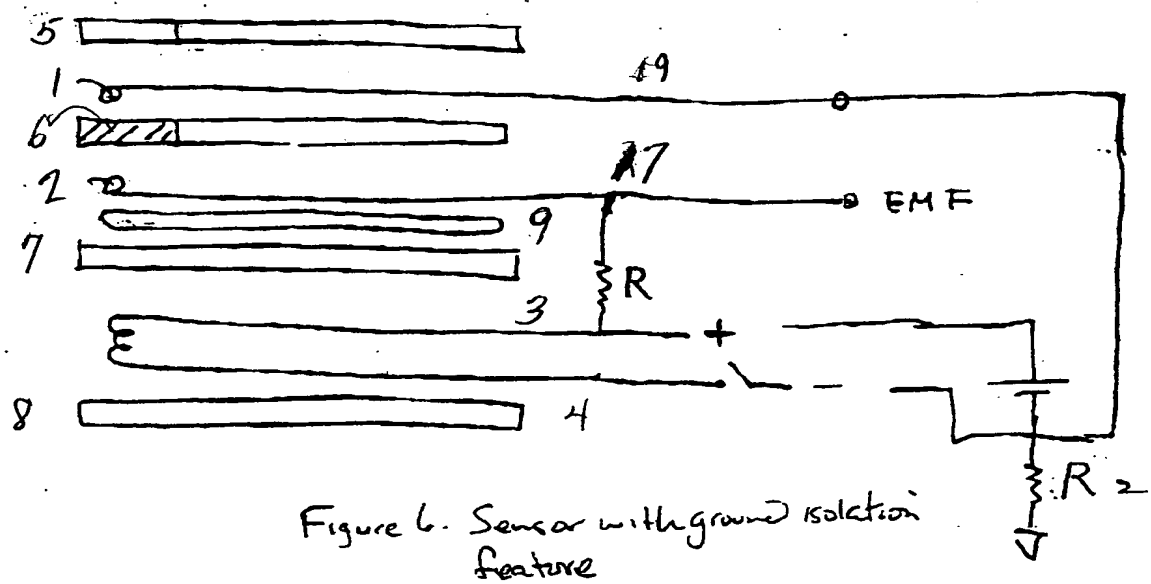


Figure 6. Sensor with ground isolation feature

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(71) Applicant *(for all designated States except US)*: **DELPHI TECHNOLOGIES, INC.** [US/US]; Legal Staff MC 480-414-420, 1450 West Long Lake Road, Troy, MI 48007-5052 (US).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **WANG, Da, Yu** [—/US]; 2188 Lancer Drive, Troy, MI 48084 (US). **CHADWICK, Wayne, M.** [—/US]; 11322 Woodbridge Drive, Grand Blanc, MI 48439 (US). **KIKUCHI, Paul, Casey** [—/US]; 12824 Clyde Road, Grand Blanc, MI 48430 (US). **GOODWIN, William, Russell** [—/US]; 5169 Georgetown, Grand Blanc, MI 48439 (US). **TAI, Lone-Wren, F.** [—/US]; 380 Silvervale Drive, Rochester Hills, MI 48309 (US). **DETWILER, Eric, J.** [—/US]; 1518 Colleen Lane, Davison, MI 48423 (US). **KENNARD, Frederick, Lincoln, III** [—/US]; 5499 East Holly Road, Holly, MI 48442 (US). **COHA, Jeffrey, T.** [—/US]; 5483 Maple Park Drive, Flint, MI 48507 (US).

(74) Agent: **CURBELO, Pamela, J.**; Cantor Colburn LLP, 55 Griffin Road South, Bloomfield, CT 06002 (US).

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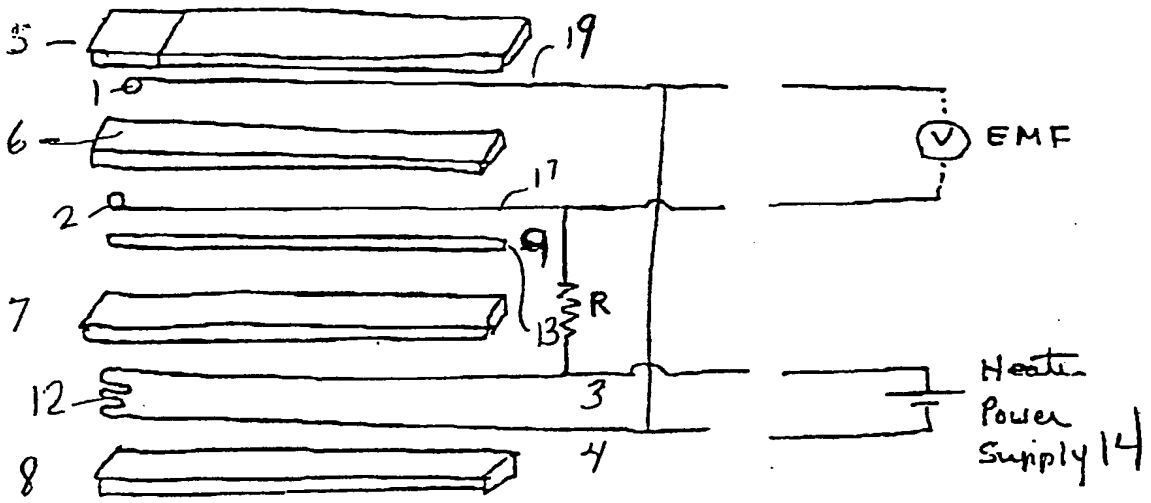
(54) Title: GAS SENSOR DESIGN AND METHOD FOR USING THE SAME



(57) Abstract: The gas sensor employs a reference gas channel which enables simultaneous or sequential pumping of oxygen and sensing of the exhaust gas (e.g., to determine if the exhaust gas is rich or lean). The method comprises: using a gas sensor comprising a first electrode and a reference electrode with an electrolyte disposed therebetween, wherein the first electrode and reference electrode are in ionic communication, and a reference gas channel in fluid communication with the reference electrode and an exterior of the sensor; introducing an exhaust gas to the first electrode; applying a voltage to the reference electrode; ionizing oxygen at the first electrode; transferring the ionized oxygen across the electrolyte to the reference electrode; forming molecular oxygen at the reference electrode; ionizing the molecular oxygen on the reference electrode; transferring the ionized oxygen across the electrolyte to the first electrode to create a voltage; and measuring the voltage.

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Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 629 535 A (OYAMA YOSHISHIGE ET AL) 16 December 1986 (1986-12-16) abstract column 14, line 8 -column 15, line 64; figures 24-28 column 5, line 64 -column 7, line 68; figure 7 ---	1-9, 16-25,32
X	DE 44 39 898 A (BOSCH GMBH ROBERT) 9 May 1996 (1996-05-09) the whole document ---	1-4,10, 15-20, 26,33
X	GB 2 270 164 A (CERAMIC TECHNOLOGY CONSULTANTS) 2 March 1994 (1994-03-02) page 4, line 6 -page 5, line 10; figures 2-4 --- -/--	1-9,12

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Name and mailing address of the ISA	Authorized officer
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INTERNATIONAL SEARCH REPORT

International Application No
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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
X	US 3 907 657 A (HEIJNE LEOPOLD ET AL) 23 September 1975 (1975-09-23) column 4, line 7 -column 6, line 43; figures 4,5	1-4,7-9, 12
X	US 4 272 331 A (HETRICK ROBERT E) 9 June 1981 (1981-06-09) column 5, line 5 -column 7, line 10; figures 5A,5B	1-9,12
X	US 4 384 935 A (DE JONG HERMAN L) 24 May 1983 (1983-05-24) abstract column 2, line 40 -column 3, line 52; figure 1	1,6-9, 16-20, 22,32
X	HETRICK R E ET AL: "OSCILLATORY-MODE OXYGEN SENSOR" IEEE TRANSACTIONS ON ELECTRON DEVICES,US,IEEE INC. NEW YORK, vol. 29, no. 1, 1982, pages 129-132, XP000886301 ISSN: 0018-9383 page 130 -page 131; figure 1	1-9,12
X	US 4 207 159 A (IKEZAWA KENJI ET AL) 10 June 1980 (1980-06-10) column 3, line 33 -column 7, line 59; figure 1 column 2, line 51 - line 57	1-4,10, 16-20,26
X	US 5 632 883 A (HOETZEL GERHARD) 27 May 1997 (1997-05-27) column 1, line 27 -column 3, line 16; figure 1	1,12,16, 17,28
X	DE 198 15 700 A (BOSCH GMBH ROBERT) 14 October 1999 (1999-10-14) the whole document	1-12, 16-28,32
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-/--

Form PCT/ISA/210 (continuation of second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Ir ational Application No
PCT/US 00/41149

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
X	PATENT ABSTRACTS OF JAPAN vol. 010, no. 072 (P-438), 22 March 1986 (1986-03-22) -& JP 60 211355 A (NISSAN JIDOSHA KK), 23 October 1985 (1985-10-23) abstract; figures 5,6	1-9,12
X	PATENT ABSTRACTS OF JAPAN vol. 013, no. 104 (P-842), 13 March 1989 (1989-03-13) -& JP 63 285462 A (NGK SPARK PLUG CO LTD), 22 November 1988 (1988-11-22) abstract; figure 2	1-9,12, 13
X	PATENT ABSTRACTS OF JAPAN vol. 013, no. 135 (P-851), 5 April 1989 (1989-04-05) -& JP 63 304151 A (NGK SPARK PLUG CO LTD), 12 December 1988 (1988-12-12)	1-9,12, 13
A	abstract; figure 2	28,29
X	US 5 049 254 A (LOGOTHETIS ELEFTHERIOS M ET AL) 17 September 1991 (1991-09-17)	1,12,13
A	figure 6A	28,29
A	EP 0 769 693 A (NGK INSULATORS LTD) 23 April 1997 (1997-04-23) figure 1A	13,29
A	US 4 784 743 A (IINO ATSUSHI ET AL) 15 November 1988 (1988-11-15) column 9, line 8 - line 25; figure 7	30
A	US 4 559 126 A (MASE SYUNZO ET AL) 17 December 1985 (1985-12-17) column 6, line 47 - line 49; figure 34	30

2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 00/41149

Box I Observations where certain claims were f und unsearchable (Continuation of it m 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

B x II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☒ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

1-13,15-30,32,33

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☒ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. Claims: 1-9,15-25,32,33

1.1. Claims: 1-9,16-25
dimensions of the diffusion limiter

problem to be solved: to provide the desired diffusion resistance (application, p.5,l.25 to p.6,l.20)

1.2. Claims: 15,33
co-firing the sensor

problem to be solved: to simplify the production process (application p.15,l.4-6)

1.3. Claim : 32
simultaneous pumping and measuring

problem to be solved: alternative measurement scheme (application p.13,l.9-16)

2. Claims: 10-13,26-30

provision of oxygen storage material or extra chamber(s) near the reference elextrode

problem to be solved: to reduce partial pressure variations at the reference electrode due to cyclic pumping (application, p.11,l.21 to p.12,l.11)

3. Claim : 14

the sensor comprises a heater and a resistor, wherein the resistor is connected to a positive heater lead and to the reference electrode

problem to be solved: to simplify the circuitry by enabling the connections to be disposed inside the sensor body (application p.5,l.12-16)

Please note that all inventions mentioned under item 1, although not necessarily linked by a common inventive concept, could be searched without effort justifying an additional fee.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US 00/41149

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 4629535 A	16-12-1986	JP 1796813 C	28-10-1993
		JP 5003547 B	18-01-1993
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US 00/41149

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP 60211355 A	23-10-1985	NONE	
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10/088427

TRANSMITTAL L[illegible]R TO THE UNITED STATES RECEIVING OFFICE

Dat[illegible]	12 October 2000 (12.10.00)
International Ap[illegible].	
Attorney Docket No.	DEP-0134 PCT

I. Certification under 37 CFR 1.10 (if applicable)

JC13 Rec'd PCT/PTO 15 MAR 2002

EL 564089724US	12 October 2000
Express Mail mailing number	Date of Deposit

I hereby certify that the application/correspondence attached hereto is being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service under 37 CFR 1.10 on the date indicated above and is addressed to Assistant Commissioner for Patents, Washington, D.C. 20231.

Barbara Latourelle	Barbara Latourelle
Signature of person mailing correspondence	Typed or printed name of person mailing correspondence

II. ☒ New International Application

TITLE	GAS SENSOR DESIGN AND METHOD FOR USING SAME

Earliest priority date (Day/Month/Year)
15 October 1999 (15.10.99)

SCREENING DISCLOSURE INFORMATION: In order to assist in screening the accompanying international application for purposes of determining whether a license for foreign transmittal should and could be granted and for other purposes, the following information is supplied. (Note: check as many boxes as apply):

A. ☐ The invention disclosed was not made in the United States.

B. ☐ There is no prior U.S. application relating to this invention.

C. ☒ The following prior U.S. application(s) contain subject matter which is related to the invention disclosed in the attached international application. *(NOTE: priority to these applications may or may not be claimed on form PCT/RO/101 (Request) and this listing does not constitute a claim for priority).*

application no.	60/159,837	filed on	15 October 1999 (15.10.99)
application no.		filed on	

D. ☐ The present international application ☐ is identical ☐ contains less subject matter than that found in the prior U.S. application(s) identified in paragraph C.

E. ☒ The present international application ☒ contains additional subject matter not found in the prior U.S. application(s) identified in paragraph C. above. The additional subject matter is found on pages throughout the application and ☒ **DOES NOT ALTER** ☐ **MIGHT BE CONSIDERED TO ALTER** the general nature of the invention in a manner which would require the U.S. application to have been made available for inspection by the appropriate defense agencies under 35 U.S.C. 181 and 37 CFR 5.1. See 37 CFR 5.15

III. ☐ A Response to an Invitation from the RO/US. The following document(s) is (are) enclosed:

A. ☐ A Request for An Extension of Time to File a Response

B. ☐ A Power of Attorney (General or Regular)

C. ☐ Replacement pages:

pages		of the request (PCT/RO/101)	pages		of the figures
pages		of the description	pages		of the abstract
pages		of the claims			

D. ☐ Submission of Priority Documents

Priority document		Priority document	

E. ☐ Fees as specified on attached Fee Calculation sheet form PCT/RO/101 annex

IV. ☐ A Request for Rectification under PCT 91 ☐ **A Petition** ☐ **A Sequence Listing Diskette**

V. ☐ Other (please specify):

The person signing this form is the:	☐ Applicant	Pamela J. Curbelo
	☒ Attorney/Agent (Reg. No.) Reg. No. 34,676	Typed name of signer
	☐ Common Representative	Signature

PCT

REQUEST

The undersigned requests that the present international application be processed according to the Patent Cooperation Treaty.

For receiving Office use only

International Application No.

International Filing Date

Name of receiving Office and "PCT International Application"

Applicant's or agent's file reference *(if desired) (12 characters maximum)* DEP-0134 PCT

Box No. I TITLE OF INVENTION

GAS SENSOR DESIGN AND METHOD FOR USING THE SAME

Box No. II APPLICANT

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

DELPHI TECHNOLOGIES, INC.
Legal Staff MC 480-414-420
1450 West Long Lake Road
Troy, MI 48007-5052
US

☐ This person is also inventor.

Telephone No.
(248) 267-5513

Facsimile No.
(248) 267-5559

Teleprinter No.

State *(that is, country)* of nationality:
US

State *(that is, country)* of residence:
US

This person is applicant for the purposes of: ☒ all designated States ☐ all designated States except the United States of America ☐ the United States of America only ☐ the States indicated in the Supplemental Box

Box No. III FURTHER APPLICANT(S) AND/OR (FURTHER) INVENTOR(S)

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

WANG, Da Yu
2188 Lancer Drive
Troy, MI 48084
US

This person is:

☐ applicant only

☒ applicant and inventor

☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality:

State *(that is, country)* of residence:

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☒ the United States of America only ☐ the States indicated in the Supplemental Box

☒ Further applicants and/or (further) inventors are indicated on a continuation sheet.

Box No. IV AGENT OR COMMON REPRESENTATIVE; OR ADDRESS FOR CORRESPONDENCE

The person identified below is hereby/has been appointed to act on behalf of the applicant(s) before the competent International Authorities as: ☒ agent ☐ common representative

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

CURBELO, Pamela J.
CANTOR COLBURN LLP
55 Griffin Road South
Bloomfield, CT 06002
US

Telephone No.
(860) 286-2929

Facsimile No.
(860) 286-0115

Teleprinter No.

☐ **Address for correspondence:** Mark this check-box where no agent or common representative is/has been appointed and the space above is used instead to indicate a special address to which correspondence should be sent.

Continuation of Box No. III FURTHER APPLICANTS AND/OR (FURTHER) INVENTOR(S)

If none of the following sub-boxes is used, this sheet is not to be included in the request.

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

CHADWICK, Wayne M.
11322 Woodbridge Drive
Grand Blanc, MI 48439
US

This person is:
- ☐ applicant only
- ☒ applicant and inventor
- ☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality:

State *(that is, country)* of residence:

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☒ the United States of America only ☐ the States indicated in the Supplemental Box

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

KIKUCHI, Paul Casey
12824 Clyde Road
Fenton, MI 48430
US

This person is:
- ☐ applicant only
- ☒ applicant and inventor
- ☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality:

State *(that is, country)* of residence:

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☒ the United States of America only ☐ the States indicated in the Supplemental Box

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

GOODWIN, William Russell
5169 Georgetown
Grand Blanc, MI 48439
US

This person is:
- ☐ applicant only
- ☒ applicant and inventor
- ☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality:

State *(that is, country)* of residence:

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☒ the United States of America only ☐ the States indicated in the Supplemental Box

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

TAI, Lone-Wren F.
380 Silvervale Drive
Rochester Hills, MI 48309
US

This person is:
- ☐ applicant only
- ☒ applicant and inventor
- ☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality:

State *(that is, country)* of residence:

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☒ the United States of America only ☐ the States indicated in the Supplemental Box

☐ Further applicants and/or (further) inventors are indicated on another continuation sheet.

Continuation of Box No. III FURTHER APPLICANTS AND/OR (FURTHER) INVENTOR(S)

If none of the following sub-boxes is used, this sheet is not to be included in the request.

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

DETWILER, Eric J.
1518 Colleen Lane
Davison, MI 48423
US

This person is:
- ☐ applicant only
- ☒ applicant and inventor
- ☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality:

State *(that is, country)* of residence:

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☒ the United States of America only ☐ the States indicated in the Supplemental Box

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

KENNARD, Frederick Lincoln III
5499 East Holly Road
Holly, MI 48442
US

This person is:
- ☐ applicant only
- ☒ applicant and inventor
- ☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality:

State *(that is, country)* of residence:

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☒ the United States of America only ☐ the States indicated in the Supplemental Box

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

COHA, Jeffrey T.
5483 Maple Park Drive
Flint, MI 48507
US

This person is:
- ☐ applicant only
- ☒ applicant and inventor
- ☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality:

State *(that is, country)* of residence:

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☒ the United States of America only ☐ the States indicated in the Supplemental Box

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

This person is:
- ☐ applicant only
- ☐ applicant and inventor
- ☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality:

State *(that is, country)* of residence:

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☐ the United States of America only ☐ the States indicated in the Supplemental Box

☐ Further applicants and/or (further) inventors are indicated on another continuation sheet.

Box No.V DESIGNATION OF STATES

The following designations are hereby made under Rule 4.9(a) *(mark the applicable check-boxes; at least one must be marked)*:

Regional Patent

☐ **AP ARIPO Patent:** **GH** Ghana, **GM** Gambia, **KE** Kenya, **LS** Lesotho, **MW** Malawi, **MZ** Mozambique, **SD** Sudan, **SL** Sierra Leone, **SZ** Swaziland, **TZ** United Republic of Tanzania, **UG** Uganda, **ZW** Zimbabwe, and any other State which is a Contracting State of the Harare Protocol and of the PCT

☐ **EA Eurasian Patent:** **AM** Armenia, **AZ** Azerbaijan, **BY** Belarus, **KG** Kyrgyzstan, **KZ** Kazakhstan, **MD** Republic of Moldova, **RU** Russian Federation, **TJ** Tajikistan, **TM** Turkmenistan, and any other State which is a Contracting State of the Eurasian Patent Convention and of the PCT

☒ **EP European Patent:** **AT** Austria, **BE** Belgium, **CH and LI** Switzerland and Liechtenstein, **CY** Cyprus, **DE** Germany, **DK** Denmark, **ES** Spain, **FI** Finland, **FR** France, **GB** United Kingdom, **GR** Greece, **IE** Ireland, **IT** Italy, **LU** Luxembourg, **MC** Monaco, **NL** Netherlands, **PT** Portugal, **SE** Sweden, and any other State which is a Contracting State of the European Patent Convention and of the PCT

☐ **OA OAPI Patent:** **BF** Burkina Faso, **BJ** Benin, **CF** Central African Republic, **CG** Congo, **CI** Côte d'Ivoire, **CM** Cameroon, **GA** Gabon, **GN** Guinea, **GW** Guinea-Bissau, **ML** Mali, **MR** Mauritania, **NE** Niger, **SN** Senegal, **TD** Chad, **TG** Togo, and any other State which is a member State of OAPI and a Contracting State of the PCT *(if other kind of protection or treatment desired, specify on dotted line)* .....

National Patent *(if other kind of protection or treatment desired, specify on dotted line)*:

☐ **AE** United Arab Emirates
☐ **AG** Antigua and Barbuda
☐ **AL** Albania .....
☐ **AM** Armenia .....
☐ **AT** Austria .....
☐ **AU** Australia .....
☐ **AZ** Azerbaijan
☐ **BA** Bosnia and Herzegovina .....
☐ **BB** Barbados
☐ **BG** Bulgaria .....
☐ **BR** Brazil .....
☐ **BY** Belarus .....
☐ **BZ** Belize
☐ **CA** Canada
☐ **CH and LI** Switzerland and Liechtenstein
☐ **CN** China .....
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☐ **CU** Cuba .....
☐ **CZ** Czech Republic .....
☐ **DE** Germany .....
☐ **DK** Denmark .....
☐ **DM** Dominica
☐ **DZ** Algeria .....
☐ **EE** Estonia .....
☐ **ES** Spain .....
☐ **FI** Finland .....
☐ **GB** United Kingdom
☐ **GD** Grenada
☐ **GE** Georgia .....
☐ **GH** Ghana .....
☐ **GM** Gambia
☐ **HR** Croatia .....
☐ **HU** Hungary .....
☐ **ID** Indonesia
☐ **IL** Israel .....
☐ **IN** India .....
☐ **IS** Iceland
☒ **JP** Japan .....
☐ **KE** Kenya .....
☐ **KG** Kyrgyzstan .....
☐ **KP** Democratic People's Republic of Korea .....
☒ **KR** Republic of Korea .....
☐ **KZ** Kazakhstan .....
☐ **LC** Saint Lucia
☐ **LK** Sri Lanka
☐ **LR** Liberia
☐ **LS** Lesotho .....
☐ **LT** Lithuania
☐ **LU** Luxembourg
☐ **LV** Latvia
☐ **MA** Morocco .....
☐ **MD** Republic of Moldova .....
☐ **MG** Madagascar .....
☐ **MK** The former Yugoslav Republic of Macedonia .....
☐ **MN** Mongolia
☐ **MW** Malawi .....
☐ **MX** Mexico .....
☐ **MZ** Mozambique
☐ **NO** Norway
☐ **NZ** New Zealand .....
☐ **PL** Poland .....
☐ **PT** Portugal .....
☐ **RO** Romania
☐ **RU** Russian Federation .....
☐ **SD** Sudan
☐ **SE** Sweden
☐ **SG** Singapore
☐ **SI** Slovenia .....
☐ **SK** Slovakia .....
☐ **SL** Sierra Leone .....
☐ **TJ** Tajikistan .....
☐ **TM** Turkmenistan .....
☐ **TR** Turkey .....
☐ **TT** Trinidad and Tobago .....
☐ **TZ** United Republic of Tanzania
☐ **UA** Ukraine .....
☐ **UG** Uganda .....
☒ **US** United States of America .....
☐ **UZ** Uzbekistan .....
☐ **VN** Viet Nam .....
☐ **YU** Yugoslavia .....
☐ **ZA** South Africa .....
☐ **ZW** Zimbabwe .....

Check-boxes reserved for designating States which have become party to the PCT after issuance of this sheet:

☐ .....

Precautionary Designation Statement: In addition to the designations made above, the applicant also makes under Rule 4.9(b) all other designations which would be permitted under the PCT except any designation(s) indicated in the Supplemental Box as being excluded from the scope of this statement. The applicant declares that those additional designations are subject to confirmation and that any designation which is not confirmed before the expiration of 15 months from the priority date is to be regarded as withdrawn by the applicant at the expiration of that time limit. *(Confirmation (including fees) must reach the receiving Office within the 15-month time limit.)*

Box No. VI PRIORITY CLAIM ☐ Further priority claims are indicated in the Supplemental Box.

Filing date of earlier application (day/month/year)	Number of earlier application	Where earlier application is: national application: country	regional application:* regional Office	international application: receiving Office
item (1) 15 October 1999 (15.10.99)	60/159,837	US		
item (2)				
item (3)				

☒ The receiving Office is requested to prepare and transmit to the International Bureau a certified copy of the earlier application(s) *(only if the earlier application was filed with the Office which for the purposes of the present international application is the receiving Office)* identified above as item(s): (1)

** Where the earlier application is an ARIPO application, it is mandatory to indicate in the Supplemental Box at least one country party to the Paris Convention for the Protection of Industrial Property for which that earlier application was filed (Rule 4.10(b)(ii)). See Supplemental Box.*

Box No. VII INTERNATIONAL SEARCHING AUTHORITY

Choice of International Searching Authority (ISA) *(if two or more International Searching Authorities are competent to carry out the international search, indicate the Authority chosen; the two-letter code may be used):*

ISA/ EP

Request to use results of earlier search; reference to that search *(if an earlier search has been carried out by or requested from the International Searching Authority):*

Date *(day/month/year)* Number Country *(or regional Office)*

Box No. VIII CHECK LIST: LANGUAGE OF FILING

This international application contains the following **number of sheets:**

request	:	5
description (excluding sequence listing part)	:	15
claims	:	7
abstract	:	1
drawings	:	6
sequence listing part of description	:	
Total number of sheets	:	34

This international application is **accompanied** by the item(s) marked below:

1. ☒ fee calculation sheet
2. ☐ separate signed power of attorney
3. ☒ copy of general power of attorney; reference number, if any:
4. ☐ statement explaining lack of signature
5. ☐ priority document(s) identified in Box No. VI as item(s):
6. ☐ translation of international application into (language):
7. ☐ separate indications concerning deposited microorganism or other biological material
8. ☐ nucleotide and/or amino acid sequence listing in computer readable form
9. ☒ other *(specify):* Transmittal Letter

Figure of the drawings which should accompany the abstract: 1

Language of filing of the international application: English

Box No. IX SIGNATURE OF APPLICANT OR AGENT

Next to each signature, indicate the name of the person signing and the capacity in which the person signs (if such capacity is not obvious from reading the request).

Pamela J. Curbelo
Applicant's Attorney

For receiving Office use only

1. Date of actual receipt of the purported international application:
2. Drawings: ☐ received: ☐ not received:
3. Corrected date of actual receipt due to later but timely received papers or drawings completing the purported international application:
4. Date of timely receipt of the required corrections under PCT Article 11(2):
5. International Searching Authority (if two or more are competent): ISA/
6. ☐ Transmittal of search copy delayed until search fee is paid.

For International Bureau use only

Date of receipt of the record copy by the International Bureau:

This sheet is not part of and does not count as a sheet of the international application.

PCT

FEE CALCULATION SHEET

Annex to the Request

For receiving Office use only

International application No.

Date stamp of the receiving Office

Applicant's or agent's file reference: **DEP-0134 PCT**

Applicant: **DELPHI TECHNOLOGIES, INC.**

CALCULATION OF PRESCRIBED FEES

1. TRANSMITTAL FEE . . . . . **240.00** T

2. SEARCH FEE . . . . . **925.00** S

International search to be carried out by **ISA/EP**

(If two or more International Searching Authorities are competent in relation to the international application, indicate the name of the Authority which is chosen to carry out the international search.)

3. INTERNATIONAL FEE

Basic Fee

The international application contains **34** sheets.

first 30 sheets **427.00** b1

4 remaining sheets x **$10.00** additional amount = **40.00** b2

Add amounts entered at b1 and b2 and enter total at B . . **467.00** B

Designation Fees

The international application contains **4** designations.

4 number of designation fees payable *(maximum 8)* x **92.00** amount of designation fee = **368.00** D

Add amounts entered at B and D and enter total at I . . . . . **835.00** I

(Applicants from certain States are entitled to a reduction of 75% of the international fee. Where the applicant is (or all applicants are) so entitled, the

4. FEE FOR PRIORITY DOCUMENT *(if applicable)* . . . . . **15.00** P

5. TOTAL FEES PAYABLE . . . . . **2,015.00** TOTAL

Add amounts entered at T, S, I and P, and enter total in the TOTAL box

☐ The designation fees are not paid at this time.

MODE OF PAYMENT

☒ authorization to charge deposit account (see below)	☐ bank draft	☐ coupons
☒ cheque	☐ cash	☐ other *(specify):*
☐ postal money order	☐ revenue stamps	

DEPOSIT ACCOUNT AUTHORIZATION *(this mode of payment may not be available at all receiving Offices)*

The RO/ **US**

☐ is hereby authorized to charge the total fees indicated above to my deposit account.

☒ *(this check-box may be marked only if the conditions for deposit accounts of the receiving Office so permit)* is hereby authorized to charge any deficiency or credit any overpayment in the total fees indicated above to my deposit account.

☐ is hereby authorized to charge the fee for preparation and transmittal of the priority document to the International Bureau of WIPO to my deposit account.

06-1130	**12 October 2000 (12.10.00)**	
Deposit Account No.	Date *(day/month/year)*	Signature

PCT

GENERAL POWER OF ATTORNEY

(for several international applications filed under the Patent Cooperation Treaty)

(PCT Rule 90.5)

The undersigned person(s) :
(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)

ASEC MANUFACTURING PARTNERSHIP

hereby appoint(s) the following person as: [X] agent [ ] common representative

Name and address
(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)

Cichosz, Vincent A.
Delphi Technologies, Inc.
Legal Staff MC 480-414-420
P.O. Box 5052
Troy, MI 48007-5052
United States of America

to represent the undersigned before

[X] all the competent International Authorities
[ ] the International Searching Authority only
[ ] the International Preliminary Examining Authority only

in connection with any and all international applications filed by the undersigned with the following Office

United States Patent and Trademark Office as receiving Office
and to make or receive payments on behalf of the undersigned.

Signature(s) *(where there are several persons, each of them must sign; next to each signature, indicate the name of the person signing and the capacity in which the person signs, if such capacity is not obvious from reading this power).*

Guy Jones, Managing Director of Partnership

Date: 1/13/00

PCT

GENERAL POWER OF ATTORNEY

(for several international applications filed under the Patent Cooperation Treaty)

(PCT Rule 90.5)

The undersigned person(s):
(Family name followed by given name: for a legal entity, full official designation. The address must include postal code and name of country.)

CICHOSZ, Vincent A.
Delphi Technologies, Inc.
Legal Staff MC 480-414-420
1450 W. Long Lake Road
Troy, Michigan 48007-5052
United States of America

hereby appoint(s) the following person as: [X] agent [ ] common representative

Name and address
(Family name followed by given name: for a legal entity, full official designation. The address must include postal code and name of country.)

CANTOR, Michael A., Reg. No. 31,152;
MURPHY, Keith J., Reg. No. 33,979;
FOX, David A., Reg. No. 38,807;
CURBELO, Pamela J., Reg. No. 34,676;
BEDINGFIELD, Herbert M., Reg.No.44,530;
LYMAN, George J., Reg. No. 44,884;
COLBURN II, Philmore H., Reg. No.35,101;
REIHER, Leah M., Reg. No. 39,341;
ELLIS, Edward J., Reg. No. 40,389;
VILLAR, Juan C., Reg. No. 34,271;
OLSON, Timothy H., Reg. No. 42,962;

Address: CANTOR COLBURN LLP
55 Griffin Road South
Bloomfield, CT 06002
US

to represent the undersigned before

[X] all the competent International Authorities
[X] the International Searching Authority only
[X] the International Preliminary Examining Authority only

in connection with any and all international applications filed by the undersigned with the following Office

United States Patent & Trademark Office as receiving Office

and to make or receive payments on behalf of the undersigned.

Signature(s) *(where there are several persons, each of them must sign; next to each signature, indicate the name of the person signing and the capacity in which the person signs, if such capacity is not obvious from reading this power):*

Vincent A. Cichosz, Agent

Date: July 31, 2000

Form PCT/Model of general power of attorney (for several international applications) (July 1992)